Weatherwise

Jet Streams and Aircraft Operations

The Movement of Hurricanes

Early Hurricanes of 1951

The Tower of the Winds

The Midwest Windstorm of October 9-10, 1949

The Greatest Flood of History

Vol. 4, No. 5, October, 1951

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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Air Weather Service Completes Functional Reorganization

The Air Weather Service has completed a reorganization of its zone of interior units as part of a program to insure a continuous improvement of its capability to provide meteorological support to U. S. Air Force and Army commands, it was announced recently by Brig. Gen. W. O. Senter, chief of the AWS.

Effective on August 1st, three new air weather groups were activated to support each of three major USAF commands regardless of the locale of their operations. The 2101st Air Weather Group, commanded by Col. James T. Seaver, Jr., located at Offutt Air Force Base, Omaha, Nebraska, will support the Strategic Air Command, which has global requirements for its long-range super bombers. The 2102nd Air Weather Group, commanded by Col. Anthony T. Shtogren, located at Langley Air Force Base, Hampton, Virginia, will support the Tactical Air Command. The 2103rd Air Weather Group, commanded by Col. Arthur A. McCartan, located at Ent Air Force Base, Colorado Springs, Colorado, will support the Air Defense Command. The 2059th Air Weather Wing, located at Tinker Air Force Base, Oklahoma, will continue to provide weather support to other Air Force commands in this country.

In 1937, the Air Weather Service became an independent service of the Army Air Corps, and it was organized on a purely geographical basis within the United States. The need for the new functional organization became apparent after World War II when the Air Force became an independent service under unification. The new setup will permit retraining of personnel for the specialized type of meteorological support required by certain USAF commands.

As previously, the Air Weather Service will continue to exercise control for the establishment of requirements for specialized meteorological equipment, and for the procurement, training, and assignment of qualified weather officers and airmen within the Air Force.

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Cover: During World War II, Boeing B-17 Flying Fortress bombers made vapor trails during high-level bombing over Bremen, Germany. These planes flew at altitudes where they encountered jet streams in the atmosphere (see page 99). Air Force photograph.

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Jet Streams and Aircraft Operations

LT. GEORGE J. GRAY, JR., HEADQUARTERS, AIR WEATHER SERVICE

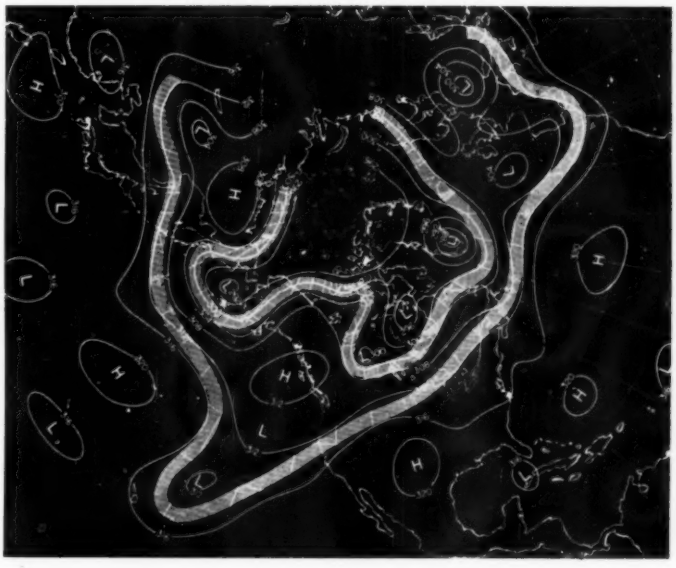
JET STREAMS are narrow currents of very strong winds that meander between 20° and 70° latitude and flow in an easterly direction. They are usually found from 20,000 to 40,000 feet above sea level. This is the region that became important as a flying level during World War II when the first high-altitude bombing missions were flown. With the advent of jet aircraft, it has become a well-traveled region for military planes, and commercial airlines are now considering this level for regularly scheduled passenger flights, since jet engines operate best in the higher altitudes. The strong winds, however, are a handicap on east to west flights.

These strong winds were christened "jet streams" by the experts at the University of Chicago early in 1947. Jet streams have nothing in common with jet aircraft other than the fact that they are found at the same altitudes and are capable of unusual speeds. The name was chosen because of the similarity that exists between these currents in the upper atmosphere and those studied for many years in oceanography, such as the Gulf Stream or the Japan Current.

As with many important scientific findings, the facts of the case were known in bits and parts for a long time by many students of the upper atmosphere. It remained for the Chicago group to organize the facts, give them a suitable name, and present a theory to explain what others had observed. The most famous cases of jet-stream winds, before they were named, were encountered during wartime bombing missions over Tokyo and Berlin, by such planes as those pictured on the front cover of this issue.

USAF bomber crews sometimes encountered such strong headwinds over Japan that in flying inland from the ocean, ground speed was reduced to practically zero; but when heading back out to sea, ground speed was nearly double the indicated air speed. We know now that jet streams of strong velocities are common over Japan at the levels and seasons at which the B-29 raids were flown.

The RAF encountered a similar situation during the famous Berlin raid of March 24-25, 1944. The group of bombers was caught in a violent wind and carried far south of the target. One aircraft found itself over Leip-



A typical spring analysis of a 300-mb chart showing undulations of jet streams in the Northern Hemisphere. Usually two jet streams cross a single meridian, but one or three wind maxima may be observed across a single meridian when an old jet is breaking down or a new one is forming. The jet streams are marked here with white stripes. The contours show heights of the 300-mb pressure level in hundreds of feet. Air Force photograph.

zig and had to fly north to Berlin; its bombs were dropped half an hour late. Another plane, which missed Berlin completely, was flying over Paris on the way home when it should have been over southern England. After the war a study of German upper-air charts showed a definite jet stream over Berlin at the time of the raid.

Jet streams must be taken seriously in planning long-distance flights. An air crew on a bombing mission cannot chance being slowed down to less than 100 miles an hour over the target. An airline company cannot afford to have its scheduled flight between New York and San Francisco delayed for several hours because of an unexpected 150-mile-an-hour headwind over Omaha. A pilot or navigator planning a long-distance, high-level flight must take advantage of the strong winds of the jet stream to shorten the actual flight time. If a jet stream is identified off course, it is sometimes wise to deviate from the normal great-circle route and join the jet stream to pick up a tailwind. If a jet stream is encountered on course as a headwind, it would perhaps be best to deviate from course to fly in an area of weaker winds.

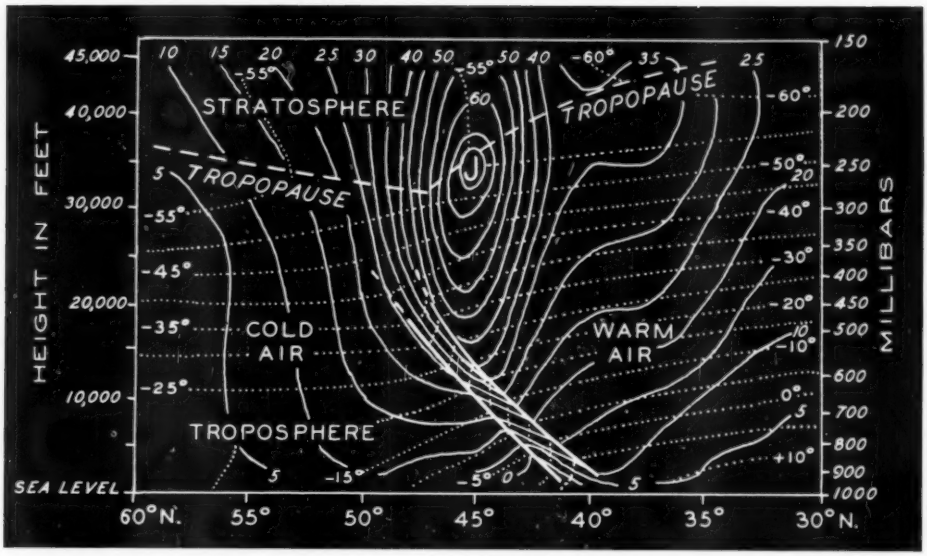
The only trouble with this approach is that it is a lot easier to say afterwards that you were in a jet stream than it is to predict the place where the strong winds will later be. In the last four years a great deal has been learned about jet streams, but wind data at high levels is still very sparse. Since the band of maximum winds is a very narrow current, and since observations are reported relatively far apart, the forecaster has a hard time pinpointing the jet stream on his weather chart.

Narrowness of the current and high speed of the winds are two major characteristics of the jet stream. The maximum speed is generally found near the 250-mb surface (approximately 35,000 feet above sea level), although jets have been reported at all levels from 15,000 feet up to 50,000 feet. This speed is well in excess of 100 miles per hour in winter, and speeds of 200 miles an hour are not unknown. Some reports have gone as high as 250 miles per hour. Jet streams are believed to be a key part of the prevailing westerlies. Consequently, they are not found in the Northern Hemisphere north of the 70th parallel or much south of the 20th.

Although theoretically the axis of the jet stream can be drawn around the world, the stream widens and weakens to such an extent that it really can no longer be considered a jet when over the eastern portions of the Atlantic and Pacific oceans. It is more appropriately considered just a broad band of westerly winds. Jet streams are often broken and move around the earth in large waves. The illustration on page 99 is an example of how the bands of maximum wind speed appeared on a 300-mb chart (30,000 feet). Some sections of the jet streams appear to run north and south or even to show a slight easterly turning. Thus, although the jet stream occurs in the westerlies, it cannot always be relied upon to furnish a strong westerly current at the required time and place.

A jet stream usually takes weeks to complete its cycle, although cases are known when the winds have disappeared in a few days. The high winds often originate between 60° and 70° north latitude, but in summer the source is on the average farther north than in winter. In one common life-cycle pattern, the maximum winds drift southward in mean latitude with an average speed of one-half to two degrees per day and reach their maximum strength at about 50° north in summer and 40° north in winter. The actual movement is difficult to determine because the jet separates, like an ocean current, into smaller streams or fans out and gets lost in the local circulation. One branch may shoot north while another branch goes south. Where a jet stream deviates from straight zonal flow, it passes south of cold lows and north of warm highs. The stream also can change altitude as it moves. Jets are usually found at higher levels in the south than they are in the north. Usually, two jet streams are identifiable at the same time, but there may be three, or only one clearly defined current when an old jet is dying. As more data is accumulated, it appears that the wind maxima of the jet streams are as basic a factor in upper-air circulation as are the major ocean currents in the movement below the sea surface.

The experts say that the best tools for locating jet streams are the 300- and 200-mb weather charts, which show a packing of contour lines and strong winds reaching their



A cross-section of the atmosphere showing the relation of the jet stream to a frontal system. The dotted contours are for temperatures.

maxima in the vicinity of the jet stream. If these very high-level charts are not available, jet streams can sometimes be found by locating a region of rapid temperature change across the wind flow on the 500-mb chart. The jet stream often occurs 10,000 to 15,000 feet above this packing of isotherms.

The diagram shows a simplified version of a jet stream associated with a frontal system — a common synoptic situation in which jet streams have been found. A north-south cross-section of the United States and Canada from about Hudson Bay to New Orleans is represented. The lines on the cross-section are average values computed from 12 cases of strong zonal winds in December, 1946 (after Palmen and Newton). Since a mean position is shown, the front is wider than it would be for an individual situation — here it would cover most of Illinois. In the diagram, we are looking down a jet stream (J) which is blowing from west to east. The cold air behind the front is moving southward, from left to right. The tropopause over the cold air is several thousand feet lower than that over the warm air. In individual cases, the tropopause over the cold air appears fairly level while that over the warm air is sloping. In the vicinity of the jet stream, the tropopause is usually broken rather than the continuous curve shown in the average picture. The strongest winds occur in the warm air south of where the front would be if it extended to 35,000 feet. The jet stream is almost directly over the front at 500 millibars and several hundred miles behind the front at the ground.

The solid lines on the diagram are isopleths or lines of equal wind speed. Their spacing indicates that the winds build up slowly to reach a maximum at the center of the jet stream. Where the lines are close together, the rate of change of wind speed, generally called wind shear, is much stronger. In this instance, the wind shear is fairly severe on both sides of the jet. In extreme cases, a decrease in wind speed of 100 knots in 100 miles has been reported north of the jet stream, and 100 knots in 300 miles on the south side. Vertically, the isopleths are relatively close together. Since cross-sections are drawn with a greatly enlarged vertical scale, it is difficult to realize at first glance that the shear above and below the jet stream is even more severe than to the north or south of it. A decrease of

(Continued on page 114)

The Movement of Hurricanes

LT. COL. NEWTON M. BURGNER
HEADQUARTERS, AIR WEATHER SERVICE

AERIAL reconnaissance and radar are doing much to help unravel the mysteries of tropical storms and their behavior. As the Air Force and Navy reconnaissance crews locate and investigate hurricanes and typhoons in desolate ocean areas, and as radar operators track them from land and in flight, new and enlightening facts are being established. Proof is growing that paths or movements of such storms are more irregular than previously suspected.

There had been a tendency to discount some fixes or locations of hurricanes made by reconnaissance flights, on the basis that poor visibility and turbulent storm conditions made exact navigation impossible. There were those who claimed that a hurricane path must approach a smooth curve. Surface ship reports of exact storm locations are relatively scarce, because such vessels attempt to escape known storms. Therefore, ship storm reports were not usually numerous enough to bring up the issue. As aerial reconnaissance increased and improved, the problem of storm location accuracy arose repeatedly, with consternation among hurricane forecasters and arguments with navigators concerning their storm locations.

It is now realized that hurricanes and typhoons move as the result of several important forces. These can cause greatly variable effects in time and space. Such influences can be classified essentially into two categories — those of external forces and those of internal forces.

The external forces are due to the air current that surrounds the hurricane on all sides and carries it along. This influence has been recognized for many years. As early as 1875, Hann noted the importance of the forces of the prevailing general current. Garriott, in "Weather Bureau Bulletin A," in 1895, and Maxwell Hall, in 1917, demonstrated how the pressure distribution and the North Atlantic high, in particular, controlled recurvature and motion of Atlantic hurricanes. Bowie, in 1922, reaffirmed that the general motion of the air over the region

The official insignia of the Air Weather Service's 53rd Strategic Reconnaissance Squadron, Medium Weather, Kindley Air Force Base, Bermuda.

in which the hurricane was located was the controlling factor of motion, and he maintained that the position of the anticyclone also controlled the speed of movement.

Mitchel, in 1924, claimed that any tropical storm will recurve into a trough of relatively low pressure that may exist when the storm arrives in the same region. Riehl and Shafer, in 1944, found storms which did not obey this rule of recurve into surface troughs. Their explanation was that the surface weather map did not show the flow pattern at higher levels. They claimed that a region of south or southwest winds aloft was required for recurve. They stated also that if the base of the westerlies lowers west of a storm at its latitude, recurvature northward will occur; and if the subtropical high is at a more northerly latitude the storm will continue westward.

Simpson, in 1946, reviewed the development of forecasting rules concerning movement of hurricanes and pointed out how the height of the theoretical "steering level" for forecasting hurricane movement pushed higher and higher as the range capability of upper-wind observations advanced higher and higher. It might be said that excellent correlation of storm movement and an upper-wind direction at some level was possible *after* the storm movement had been observed, but the problem of proper level selection prior to storm movement still remained.

The subject of steering level has been a much debated one. Strictly speaking, steering should refer to the forces that guide a very small disturbance in a broad current. It seems strange to think of a hurricane or typhoon as a small entity, but that is the relative dimension that should be considered in association with any steering or broad-scale controlling current. It is more realistic to think in terms of a "steering layer" of the atmosphere rather than a steering level. It should also be realized that if the hurricane or typhoon is so extensive that it cannot be considered as embedded in a controlling current, the idea of steering cannot be applied.

Quantitative testing of this principle was made for storms of the 1947 season in the Atlantic by correlating the zonal component of storm motion with the zonal component of the steering current. These zonal components were found to be equal, on the average, when the zonal current region of influence was considered as the quadrant extending from 45 degrees east to 45 degrees west of a storm center.

With realization of the importance of the external influence of the associated synoptic pressure pattern as it affects the storm movement, it became evident that the problem of forecasting the future path of a hurricane was largely one of forecasting the associated upper-level conditions. The importance of this fact was forcefully presented by Klein and Winston in their study of the great September 4-20, 1947, hurricane, which struck both Miami and New Orleans. They showed that the entire circulation pattern over the United States made a radical reversal in three days and that dynamic anticyclogenesis over the eastern United States, caused by rapid spread of energy downstream from the mid-Pacific, blocked the storm and forced it to move west into the Gulf of Mexico instead of recurving up the Atlantic coast.

The discovery and evaluation of hurricane internal forces which act to influence movement have developed mainly through theoretical research. In brief, they appear to be forces which produce:

1. Northward displacement approximately proportional to the storm intensity.

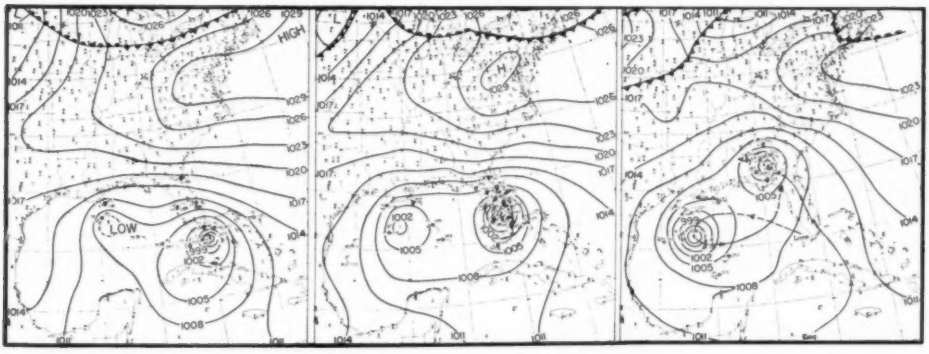
2. Westward displacement, which tends to decrease in relation to northward storm movement.

3. Periodic displacement of small amplitude about the mean track.

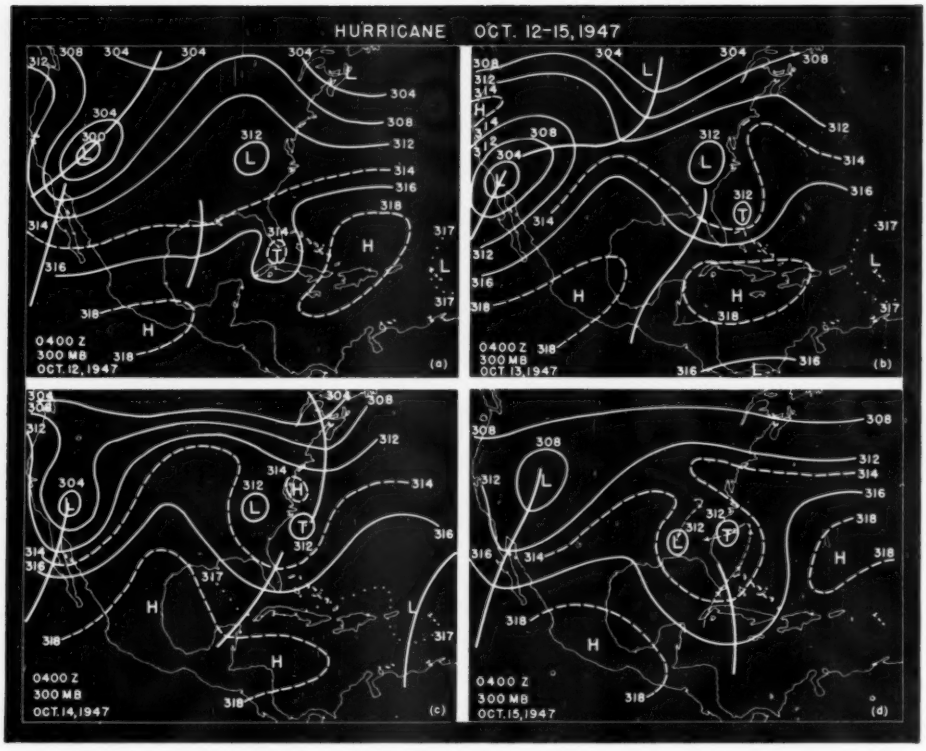
Rossby, in 1949, and Davies, in 1948, working independently, arrived at realization of the first type of influence — there are internal tropical storm forces tending to drive storms across latitude circles.

Moore, in 1946, presented the idea of the second type of force. He claimed that tropical storms are asymmetrical and move in the direction of the strongest winds in the outer isobaric channels of the storm. He developed a method for forecasting direction of motion and speed by using wind observations on the same isobar around the storm center.

The third type of internal influence, which was advanced by Yeh, in 1949, has done much to explain the difference of opinion between airplane navigators and forecasters as to the exact location of a tropical storm;



Surface charts for (left) October 17, 1950, 1930 EST; (center) October 18, 0730 EST; and October 19, 0730 EST, with paths of the hurricanes marked. From the *Monthly Weather Review*.



These are 300-mb charts for October 12-15, 1947. The contour heights are in hundreds of feet: solid lines for 400-foot intervals, broken lines, 200-foot, and dotted lines, 100-foot intervals. The heavy solid lines indicate trough positions. The tropical storm is marked by "T." Tracks on part d show hurricane and secondary-low paths at 300 millibars. Air Weather Service chart.

Yeh demonstrated that interaction of storm and environment introduces oscillatory effects into the storm track. He also prepared graphical forecasting aids for use of this principle.

It is probable that there are still other undiscovered forces which play their part in controlling movement of hurricanes and typhoons. When it is realized that all these internal and external forces are in action and that their separate degrees of influence may vary in intensity and time, it is understandable that a tropical storm track can be irregular and fluctuating.

The results of research and study carried on by many other meteorologists have contributed to the advancement of knowledge concerning tropical storm movement. It is impossible to discuss or refer to their efforts in this brief space, but the work of the Japanese school, and of Fujiwhara, in particular, should be noted.

In 1922, Fujiwhara showed how two cyclonic centers tend to rotate cyclonically around each other. This condition can be considered as a special type of combination internal-external forces effect. An example of this so-called Fujiwhara effect is found in hurricanes KING and LOVE of the 1950 season. As described by Norton in the January, 1951, issue of the *Monthly Weather Review*, KING was a small, but violent, hurricane that passed directly over Miami on October 17th. It had formed in the northwestern Caribbean Sea on October 15th and moved on a northeasterly course past the western end of Jamaica, then turned northward across Cuba during the 16th. After leaving the Miami area, the center continued on a north-northwesterly course through eastern Florida into

Georgia. (See also WEATHERWISE, December, 1950.)

Storm LOVE began forming in the Gulf of Mexico south of the Louisiana coast at the time KING was moving northward through Florida on the 18th. This center described a counterclockwise path and moved down into the central Gulf on the 19th, increasing to hurricane force. On the 20th, the storm completed a track to the east and northeast, losing force due to the influence of dry air in the system. The relative counterclockwise storm paths under the influence of the Fujiwhara effect are illustrated by the third chart on page 103.

Another interesting situation is presented by the hurricane of October 12-15, 1947. This storm developed off the coast of Nicaragua, moved northward across western Cuba, curved northeastward across the tip of Florida, and appeared to be on a "harmless" course into the Atlantic when it suddenly curved west-southwestward from approximately 300 miles off shore and moved inland to batter Savannah, Georgia, with winds of 90 miles per hour.

A series of 300-mb charts for October 12-15, 1947, is presented here. In this case, there was a second low center associated with the hurricane circulation at the 300-mb level. The possible Fujiwhara effect is indicated by the relative counterclockwise rotation of the two centers shown in the diagram.

There was, however, another important influence at work as an external force at upper levels. Anticyclonic intensification that developed over the southwestern United States on October 13th moved downstream and built up the ridge of high pressure off the East Coast, so that it extended westward to the north of the hurricane by the 15th. The blocking action of this ridge interrupted the northward progress of the hurricane and also caused it to swerve westward into Georgia.

This situation illustrates how several types of forces contribute to the movement of tropical storms. It also points out the importance of considering the large-scale synoptic patterns and the various influences that are at work. As knowledge of these forces increases and as techniques of broad-scale synoptic forecasting improve, the technique of hurricane movement forecasting will advance.

EARLY HURRICANES OF 1951

LESS than the normal number of storms occurred during the first half of the 1951 hurricane season, but it started earlier than ever before, and two of the storms traced unusual tracks with respect to each other.

ABLE: This storm was described on page 67 of **Weatherwise** for June, 1951, the earliest North Atlantic hurricane in weather history. Its erratic motion is shown on the chart on the next page.

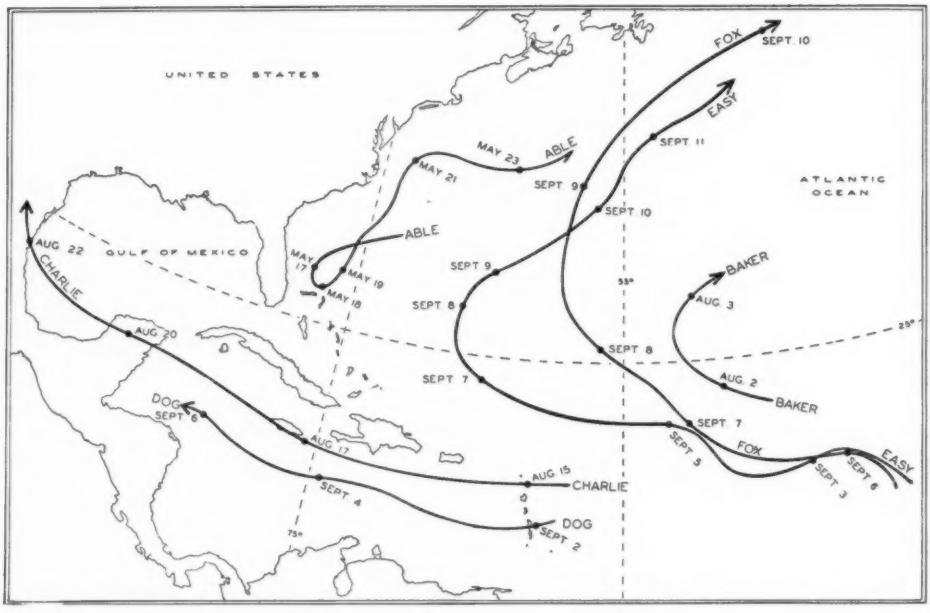
BAKER: A tropical storm was detected far southeast of Bermuda on August 2nd by aircraft reconnaissance. It recurved early and passed into the mid-Atlantic without approaching any islands.

CHARLIE: This was a hurricane of major proportions and one of the most destructive in history. It formed east of Antigua on August 14th, crossed near that island on the 15th doing major damage, and then set out across the Caribbean. The center passed over Jamaica near Kingston on the night of August 17-18, when winds of 140 miles per hour and rainfall of 17 inches were reported. Major damage, estimated up to 50 million dollars, was done to buildings and crops, and more than 100 persons were reported killed. The old city of Port Royal was wiped out.

The great whirl reached the Yucatan peninsula of Mexico on the 20th, losing some of its force over land, but when once again over the open seas of the Gulf of Mexico it regained energy and crossed the coastline just north of Tampico. It rammed against the inland mountains, and loosed a torrent of rain that swept away in flood waters many buildings and installations. Several hundred lives were lost in the mountain country of northeastern Mexico during the next days as the rains continued. The moisture put into the general circulation by this storm reached all the way to Arizona and southern California, where the heaviest rains in 10 years were reported.

DOG: A squally area very near the island of Martinique in the Lesser Antilles developed a hurricane circulation on September 2nd and gave that island its worst beating in 20 years. It then took a course over the open Caribbean just south of the major storm of mid-August. Jamaica prepared for another severe blow, but the circulation soon collapsed, with high winds sustained only on the northern crescent. This drifted westward to a point near Swan Island, but reached no land area in force.

EASY: This large hurricane was detected on the 3rd of September. As shown on the map, it made a westward course for four days and seemed headed for the North America mainland,



The paths of the first six hurricanes of the 1951 season.

but it recurved on the 7th southwest of Bermuda, when its winds were at a peak, estimated at 160 miles per hour. This change in direction brought the storm in line with Bermuda, and that island was put on the alert for its first major blow since the storm of 1947. But the recurving continued as the storm passed 100 miles south of Bermuda and thence northeastward. It could still be identified as a tropical storm on the 12th of September.

FOX: Another hurricane formed in almost the same spot as EASY, just three days later. This was a smaller but faster moving storm. It recurved early when southeast of Bermuda and by September 8th was abreast of EASY 500 miles to the east, at latitude about 27° north. FOX passed into an existing trough of low pressure and sped north at about 60 miles per hour into the North Atlantic shipping lanes. There it merged with the Icelandic low, which was very well developed.

The movement of EASY with respect to FOX was very interesting, though not quite as spectacular a maneuver as some newspaper accounts indicated. EASY had also made for the trough of low pressure, but it moved northeastward at a much slower speed than FOX. The circulatory systems of these two hurricanes came into contact, no doubt, as both made for the channel provided by the trough of low pressure. A thorough analysis of this apparent clash of two major hurricanes will be eagerly awaited by the meteorological profession.

HOT WEATHER IN TEXAS

The summer of 1951, one of the hottest on record for Texas, was remarkable for the duration of the heat rather than its intensity. No new absolute maximum marks were set, but from July 3rd to September 8th the heat regime remained unbroken throughout the central part of that state.

The metropolitan area of Ft. Worth and Dallas suffered in particular. In the 69-day period, the maximum temperature at Meacham Field was 95° F. or above every day. On 41 occasions the mercury soared above the 100° mark. The absolute maximum of 107° was reached on several days, but this fell short of the all-time high of 112°. Coming after a hot July, August was the hottest month ever experienced at the two Texas cities, with an average of 90.3°, the only 90° month on record. On no occasion did the nighttime minimum fall below 71° F.

After a cold front passage on July 2nd, which dropped 1.85 inches of rainfall, a prolonged drought set in. The rest of July registered only 0.35 inch of rain. The August total came to 0.47 inch, and the first eight days of September received only 0.05 inch — a total of 0.87 inch for the bulk of the summer season. A cold front finally succeeded in penetrating the area on the night of September 9-10, breaking the dry spell and bringing the mercury down to comfortable levels for a brief period.

THE MIDWEST WINDSTORM OF OCTOBER 9-10, 1949

LYNN L. MEANS, U. S. WEATHER BUREAU, CHICAGO, ILLINOIS

ON the afternoon of October 9, 1949, a low pressure area began deepening and moving rapidly northeastward from New Mexico. A day later it was crossing the border into Canada with a central pressure of less than 970 millibars. It left in its wake a trail of 22 persons killed and damage to property of staggering proportions. It blew over a 300,000-pound coal-carrying crane near Boulder, Colorado, leveled oil derricks as accompanying tornadoes ripped through central Kansas, caused a track washout and a train wreck.

Damage was everywhere — trees uprooted; planes wrecked; corncribs, barns, silos, drive-in theaters, and billboards destroyed. Widespread damage occurred to small boats and docks along the Mississippi River, on small inland lakes, and on Lakes Michigan and Superior. Crops still in the fields were blown to the ground, the loss in Iowa alone amounting to five to 7½ bushels per acre. This hindered harvesting, and in many cases livestock had to be turned into the fields to consume the grain. Insurance claims in Iowa were the highest in history for a single storm.

THE SYNOPTIC SEQUENCE

The low first appeared as a separate entity on the sea-level pressure chart on the morning of October 8th, located over northern Arizona and southern Utah, where it had formed as a secondary or residual system, while another low associated with a weak wave moved northeastward along the polar front. On the 700-mb surface, which was of greater significance considering the high-altitude topography, a closed low was located just west of the residual surface low.

The patterns moved slowly eastward on the evening of the 8th and the morning of the 9th. Meanwhile, significant 12-hour falls in pressure were noted in northwestern Canada on the morning of the 8th. This area of falling pressure moved southward to the United States border by early on the 9th, and subsequently southeastward before recurving northeastward with the deepening low.

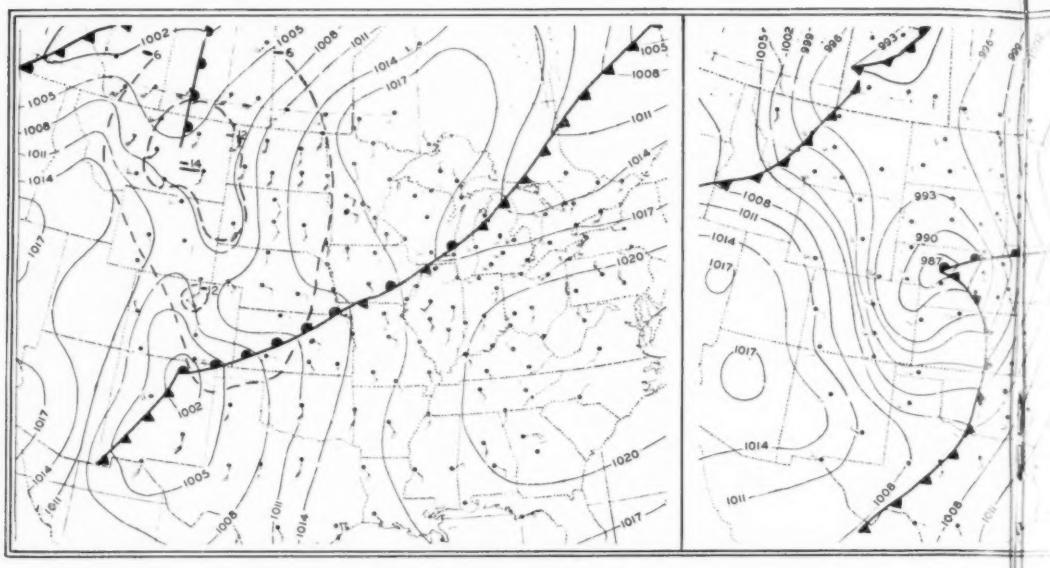
The trajectory of the low, illustrated here, corresponded fairly well to the location of the central portion of the 200-mb jet stream at the beginning of the period of deepening, but with more cyclonic curvature.

As for the air masses involved, a shallow cold layer of modified polar continental and polar maritime air lay over the northern plains and upper Mississippi Valley. Warm moist tropical maritime air with dew points in the upper 60's and lower 70's covered the southern plains.

Considerable pre-trough thunderstorm and tornado activity occurred the afternoon and evening of the 9th, especially in central Kansas. Some evidence was seen of two or more separate "bursts" of activity, although the occurrence of isolated individual tornadoes seemed to obscure any simple progressive pattern.

By evening, considerably more moisture had moved into the northern plains, with a dew point of 12° C. aloft at 5,000 feet over St. Cloud, Minnesota. The last few tornadoes were occurring in the vicinity of and just ahead of the cold front from central Oklahoma to eastern Nebraska, as the cold front began to show rapid movement across Kansas. The low was now deepening rap-

The location of the cyclone center and the lowest pressures reported. Times are Central standard; pressure is in millibars.



The synoptic conditions associated with three positions of the storm are shown here. *Left to ri*

idly, although no pronounced temperature contrast was present across the surface front. The storm occurred too early in the season to be followed by severe cold, although minimum temperatures were slightly below freezing in portions of the northern Rockies and northern plains.

Winds and Precipitation

Most damage was due to the sustained high winds which swept the north-central states, with gusts occasionally greater than hurricane force. The strongest gusts occurred on the 10th in the vicinity of and to the rear of the cold front, diminishing behind a secondary cold front. Rochester, Minnesota, reported gusts to 100 miles per hour; Minneapolis winds held 50 miles per hour for 3½ hours, with gusts to 80.

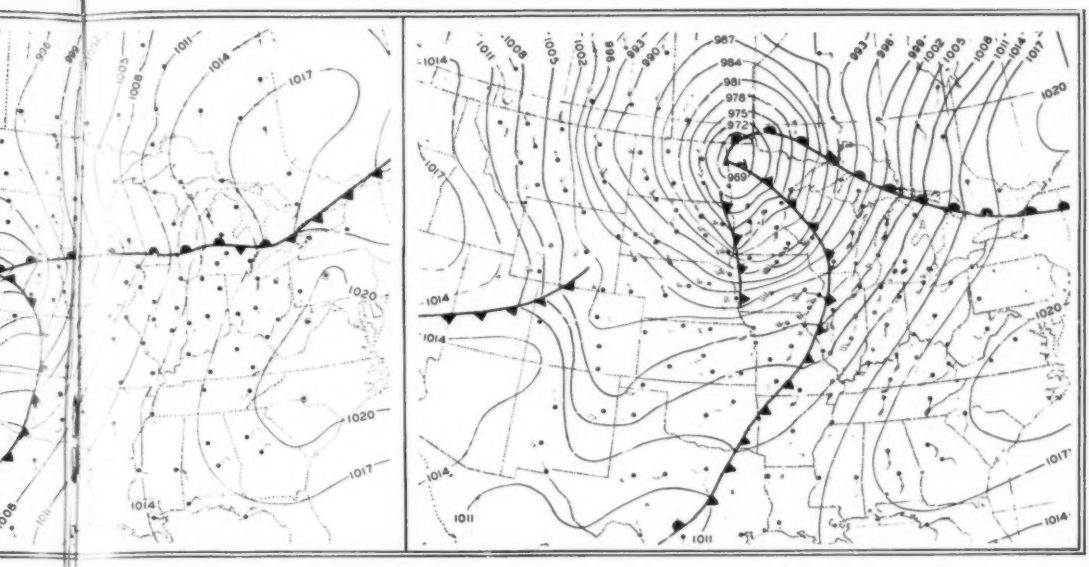
Pressure had continued to fall in this area to the rear of the cold front, waiting passage of a secondary trough. Lapse rates were quite steep in the cold air mass. This, together with very strong winds aloft, contributed to downward transport of momentum and thereby to the maintenance of the high surface winds. Pilot balloon observations were missing in the area of strongest surface winds. However, at 0900 CST October 10th, Milwaukee reported a wind of 75 knots from the south-southwest at 4,000 feet. Des Moines had southwest 94 knots at 8,000 feet. By midafternoon, Green Bay, Wisconsin, reported south-southwest winds, 119 knots at 6,000 feet.

By evening of the 10th the extreme gustiness had subsided and wind speeds in general were slowly diminishing. They continued to lessen slowly throughout the night, as the center passed rapidly into Canada.

Precipitation amounts were largest in squalls preceding or attending the cold front. Dodge City, Kansas, reported 2.98 inches for the six-hour period ending 1830 CST October 9th. This occurred in a pre-frontal thunderstorm. North of the warm front, precipitation amounts were mostly less than one-half inch until the final half of the period of deepening, when six-hour amounts increased to one-half to 1½ inches just ahead of the warm front.

The Deepening

Twelve to 24 hours before the deepening began, the 700-mb trough in the western United States showed signs of moving eastward, as indicated by both the height-change patterns and the long-wave analysis. As the sea-level low moved north-northeastward in the flow ahead of the major trough, the up-



Left to right: October 9, 12:30 p.m. CST; October 10, 12:30 a.m.; October 10, 12:30 p.m. USWB charts.

per trough itself, even at the 200-mb level, was moving eastward, so that the lower system was exposed to pressure falls throughout a deep layer as the upper system overtook it.

On the October 8th, 0900 CST 700-mb chart, cold air was being advected into the lower portion of the western 700-mb trough. But marked warming occurred over that area at the 200-mb level; at Las Vegas, the 200-mb temperature rose 16° C. in 24 hours. This was probably due to descent of potentially warmer stratospheric air. This was 24 hours before the beginning of deepening of the sea-level low. The appearance "in situ" of such warming at the 200-mb level has been observed prior to deepening in other cases.

Rapid deepening in the northeastward-moving low coincided to some degree with the arrival east of the central Rockies of the advance portion of the previously mentioned area of pressure falls that moved southeastward from western Canada. This "explosive" effect is well known to forecasters. Recognition of some of its antecedent prerequisites constitutes one of the more valuable uses of 12-hour pressure-change charts.

Moderate to strong southerly winds in the lower layers continued to transport warm, moist, relatively unstable air northward into the area immediately ahead of the low.

The deepening came to a halt as the sea-level low approached the point of confluence of the northern and southern branches of the 200-mb jet. By this time, considerably cooler and drier air had moved into the lower layers (700 millibars and below) with a corresponding decrease in precipitation. The appearance of the soundings over the center of the low, as interpolated from constant-pressure charts, suggested the upward movement of an equivalent potential temperature wave from 850 millibars to 500 millibars through the 24-hour period of deepening.

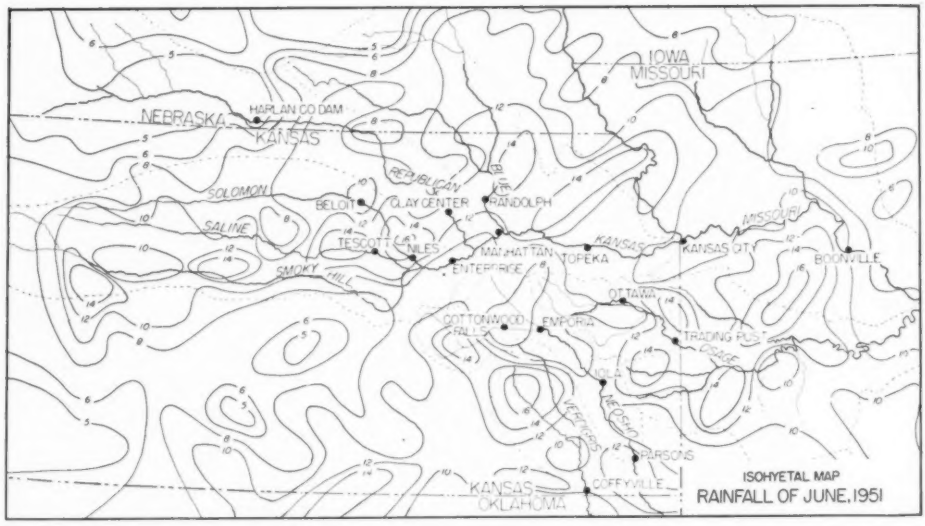
In summary, the following factors were associated with the deepening of the October 10, 1949, storm:

1. The eastward movement of a major trough aloft with a tendency to overtake the sea-level low.

2. Prior development "in situ" of warm air at the 200-mb level over cold advection (700 millibars) on the forward side of the trough aloft.

3. Southeastward movement of an isallobaric wave from northwestern Canada to the west-central plains states.

4. Accelerated flow of moist, light, unstable air northward into the path of the advancing low.



The distribution of rainfall during the month of June, 1951. The lines are of equal rainfall, and the depths are marked in inches. USWB chart.

The Greatest Flood of History

VERNE ALEXANDER, NORTH CENTRAL AREA HYDROLOGIC ENGINEER
UNITED STATES WEATHER BUREAU

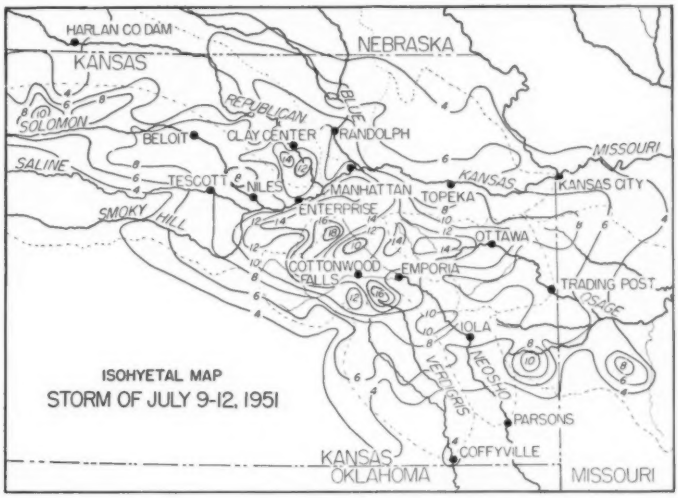
THE most devastating flood in the nation's history struck the Middle West July 13, 1951. The focal point with respect to damage was in the industrial districts of Kansas City, Kansas, and Kansas City, Missouri. Preliminary estimates indicate one billion dollars physical damage and an equal loss due to interruption of business and production. A loss of 17 lives may be attributed directly to the flood.

The meteorological situation producing the excessive rainfall was the result of blocking the westerlies over the Pacific, high pressure and low temperature over the northern plains, and a continuous flow of warm moist air from the Gulf of Mexico. The preceding month of June was the wettest in the 65-year weather history of the state of Kansas. The state average of 9.55 inches was 5.58 inches above normal. The isohyetal map shows the

This sun-baked silt and mud that covers the streets of the two Kansas Cities was deposited during the flood. Wide World photograph.

distribution over the state. These rains caused serious flooding and left the soil saturated.

Rainfall leading to the disastrous flood of July 13th fell from the night of July 9-10 through the morning hours of July 12th.



The excessive rainfall pattern during the 72-hour period, July 9-12, 1951. USWB chart.

During this period, some official Weather Bureau gages measured over 14.50 inches and over 17 inches was reported from unofficial gages. The second isohyetal map, for the period July 9-12, illustrates the areal coverage of this 72-hour storm. Preliminary calculations show the average rainfall over 20,000 square miles was almost 10 inches, making it the greatest 72-hour storm of record north of the 37th parallel.

The center of this excessive rainfall was near the divide between three major river basins. From a meteorological viewpoint, this center could have occurred 75 miles farther north, thereby contributing about 40 per cent more precipitation to the Kansas basin.

Record-breaking river stages on the Kansas, Osage, and Neosho rivers were experienced. On the Kansas at Topeka the crest was 3.7 feet higher than the 1903 flood, and on the Osage at Ottawa, Kansas, it was 4.5 feet higher than the record set in 1928. The flood on the Neosho was the most outstanding, with a crest at Parsons, Kansas, 9.0 feet higher than all previous records. Official weather and river observers deserve the highest commendation for efforts to report promptly current observations to the Weather Bureau for river forecast purposes. These reports, to a great extent, were responsible for the reduction in loss of life and property. In a less severe flood in 1903, it is estimated 350 people were drowned, a contrast to 17 in July, 1951.

Very valuable hydrologic data have been collected by the U. S. Weather Bureau and the U. S. Geological Survey. This information is being compiled and will appear in considerable detail in official reports of these agencies. Weatherwise citizens of the area have made valuable contributions to this collection through reports from unofficial gages.

ANNULAR ECLIPSE WEATHER

The annular eclipse of September 1st, described in WEATHERWISE in August, was observed favorably from scattered points along the path of the annular phase. The coastal region around Norfolk was foggy, but perfect rings were photographed at Winston-Salem, North Carolina, and Philpott Dam, Virginia. Pictures and observations by amateur astronomers are being published in **Sky and Telescope** for October and November, published at Harvard College Observatory in Cambridge, Massachusetts.

Cloudy weather also prevailed over New England and New York state, and in the Middle West, spoiling observations of the partial eclipse for most of those portions of the United States that were to have viewed it after sunrise.

The Tower of the Winds

PHOTIOS P. KARAPIPERIS

NATIONAL OBSERVATORY OF ATHENS AND BLUE HILL METEOROLOGICAL OBSERVATORY

AMONG the earlier buildings of the Roman period in Athens, there is the Horologion or Tower of Andronikos of Kyrrhestes or Kyrrhos, popularly known as the Tower of the Winds. This building belongs to the second or, more likely, to the first century B.C. (at any rate, no later than 37 or 35 B.C.). It was used to tell the hours of the day, the seasonal position of the sun, and the wind direction. It is situated on the north side, close by the base of the Acropolis, and near the porticos of the so-called Roman agora of the ancient city, part of which must have been built at the same time as the tower, if not earlier.

The tower has been preserved in almost its entirety through 2,000 years. It is an octagonal, marble structure, about 43 feet in height and 26 feet in diameter, with two porticos, on the northeast and northwest sides, each of which had two Corinthian columns. The upper portion of the building is encircled by a frieze, the eight sides of which face the eight points of the Athenian compass and, in bas-relief, illustrate male personifications of the characters of the wind.

The Tower of the Winds at Athens, Greece, from a photograph in *The Climate of Athens*, by D. Eginitis, Athens, 1907.

All the figures face to the right, have wings, and also wear a kind of buskin except two of them, which have their legs and feet bare. They symbolize the prevalent features of the winds of Athens. So the cold, fierce, and stormy north wind is represented by BOREAS (*Borras* in modern Greek), a bearded old man, warmly clothed, and holding a conch shell near his mouth, suggesting the noise made when this wind is blowing.

The northeast wind, KAIKIAS, is cloudy and cold, bringing snow at some seasons and also thunderstorms and hail. This wind is the prevailing one at Athens, in modern times, during all the months of the year, except April, May and June, and is mentioned by Aristophanes as an unsteady wind in Attica. He is also represented as a well-clothed old man, but with his arms bare. He is holding a shield half full of hailstones, but tipped up as if ready to rattle them down on the countryside.

APHELIOTES (blowing from sun), the east wind, is a favorite one, with frequent light showers and, therefore, a great friend of vegetation. The sculpture represents this wind as a fine young man with his arms full of a variety of fruits, grains, and perhaps vegetables.

The only one of the winds who carries nothing in his hands, an old man well wrapped in his mantle and with a longer tunic than that belonging to any others, is the southeast wind, EUROS. This wind brings much rain at Athens, and so is characterized by Hesiod as a wet wind and by Homer as a stormy wind.

The sultry and very wet south wind, the

master of the warm rain, NOTOS, a name still used today, is represented by a young man lightly wrapped. He carries with him a water jar which has just been emptied.

The figure on the southwest face of the tower, LIPS, apparently represents the prevalent sea breeze, which at Athens comes usually from the southwest. The sculpture represents this wind by the figure of a young man with his legs and feet bare and carrying in his hands a piece of a trireme (ancient ship). With respect to the meaning of this symbol, it may be noted that this wind, when light, favors the entrance of ships to the port of Piraeus. Occasionally, however, as a strong wind, the famous sirocco, it is the terror of navigators at the present time. Today the name LIPS is popularly applied only to hot winds, and whether or not they are from the southwest.

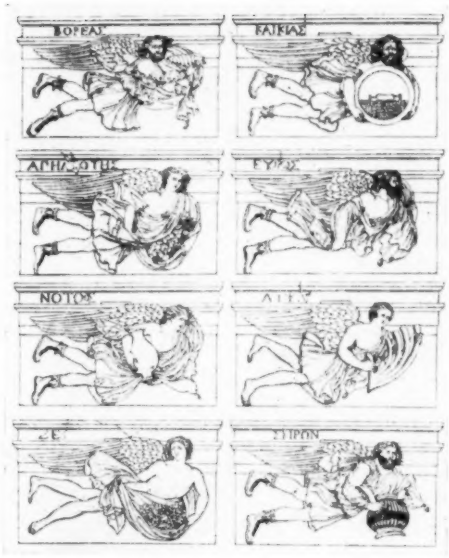
ZEPHYROS, the west wind, is figured as a beautiful youth, wearing only a loose mantle, the skirt of which is filled with flowers. This wind is mentioned by Homer in the *Iliad* as being strong and stormy, but in the *Odyssey* as being light, causing the vegetation to grow and fruit to ripen.

The northwest wind, SKIRON, is the driest at Athens, bringing cold during the winter, and also hot and dry air from the interior of Boeotia, and lightning, during the summer. So in every season he is a disagreeable, annoying visitor. He is depicted on the Tower of the Winds as an old man warmly clothed, like BOREAS, and is holding a vase different from that held by NOTOS. This seems to be a brazen fire-basket, symbol of dryness, from which ashes and burning coals are scattered. That it is a vase of "plenty," as has been asserted, does not seem probable.

The roof of the building was originally surmounted by a bronze weather vane in the form of a Triton holding a rod and turning freely on a pivot.

The structure is called also Horologion because it was used to indicate or measure the time.* During the day, the time in sunny weather was indicated by a series of sundials, incised on the external marble walls of the tower, and of these the lines still are to be seen. During the night, and on cloudy days, the time was measured by a kind of water clock, a clepsydra. This instrument was a special vase, which was filled with water and then allowed to empty slowly and steadily through a small hole. Its original use is referred to by the ancient Athenian law courts. Traces of such a clepsydra are still to be seen on the center of the floor in the interior of the tower. This water clock may have been supplied from a spring on the Acropolis, and also the hours may have been sounded by a special instrument operated by means of this mechanism.

The Tower of the Winds is the emblem of the Royal Meteorological Society. Photographs of the tower or of the figured winds decorate several books and magazine articles. Copies of the eight bas-reliefs decorate the outside of the octagonal tower of the Radcliffe Observatory, England, and the corners of the library of the Blue Hill Meteorological Observatory of Harvard University.



Drawings of the bas-relief figures on the Tower of the Winds at Athens. Those for the four cardinal points, north, east south, west, are in that order from top to bottom on the left side: Boreas, Apheliotes, Notos, and Zephyros. Those for the intermediate points, northeast, southeast, southwest, and northwest, are on the right, Kaikias, Euros, Lips, and Skiron. From a book by A. Baumeister, Munich, 1889.

*The assumption that the tower was made octagonal with symbolic figures of the winds for artistic purposes alone seems untenable.

LOW HUMIDITY IN NEW MEXICO

June, 1951, marked the first time in 20 years of reliable humidity observations at Albuquerque that the relative humidity ever dropped below four per cent in that month. A complete search of the records has not been made, but the three-per-cent humidities observed this June probably set the all-time low for this station.

The most remarkable thing about this year's observations is the occurrence of the extremely low humidity at the 11:25 p.m. observation on June 22nd, and again at 10:25 p.m. on June 26th. One might expect such low values during the heat of the day, but certainly not late at night. Altogether, there were seven days in June, 1951, when the relative humidity dropped to three per cent, with a total of 18 hours duration. On June 23rd, the highest humidity of the day was 10 per cent. During the possible 720 hours of the month, a humidity of less than 10 per cent was observed for 242 hours, or 33.6 per cent of the time.

A private communication from the central office of the U. S. Weather Bureau refers to two psychrometric observations in California a few years ago, which yielded improbable (zero or negative) values of atmospheric vapor pressure as computed by means of the Ferrel psychrometric formula. These results suggest the inference, at least tentatively, that the formula is not strictly reliable at extremely low relative humidities.

These data, in addition to rainfall information available elsewhere, indicate the reason that this summer was the worst fire-weather season of record for New Mexico forests.

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Albuquerque, N. M.

JET STREAMS AND AIRCRAFT OPERATIONS

(Continued from page 101)

100 knots in 12,000 feet above or below the center of the jet is by no means uncommon.

Light to moderate clear-air turbulence has been found in the jet stream in the vicinity of the tropopause. Severe clear-air turbulence has also been encountered there on rare occasions. Clear-air turbulence occurs in small unpredictable patches; hence it is unlike the sustained roughness felt when flying in convective clouds or at low levels.

At present, Air Force experts on the jet stream are looking forward to the time when they will be able to analyze it directly. An analysis is now a time-consuming task, which requires the construction of pressure-contour charts and the extrapolation of winds up to the higher levels. New equipment recently put into operation at some Air Force bases provides reliable wind data to higher levels than previously. If and when this equipment or a similar type comes into general use throughout the world, not only the jet stream, but the entire wind field will be much more clearly defined.

THE 1950 NOVEMBER STORM

The great storm of the last week of November, 1950, consisted of three main phases: a record early season cold wave in the Gulf and South Atlantic states, the greatest snowstorm on record in adjoining parts of West Virginia, Pennsylvania, and Ohio, and the most prolonged windstorm on record in the Middle Atlantic and New England states. This storm was described in the February, 1951, WEATHERWISE; final statistics were published recently in the Weather Bureau's national summary of climatological data, and include the following facts:

Pressure: Lowest, 978 millibars or 28.88 inches, Akron, Ohio.

Temperature: State November records, Alabama, −2° F.; Arkansas, 0°; Georgia, 0°; Indiana, −10°; Michigan, −23°; Mississippi, 4°; Missouri, −12°; South Carolina, −1°; Tennessee, −8°; Virginia, −3°.

Rainfall: State maxima, Seabrook, N. J., 6.57″; Plattville, Pa., 6.86″; Slide Mountain, N. Y., 7.78″; Pinkham Notch, N. H., 6.04″.

Snowfall: Greatest storm depth, 57.1″ at Pickens No. 1, W. Va., with several readings above 50 inches nearby.

Wind: Highests gusts, Hartford, Conn., 100 mph ESE; Newark, N. J., 108 E; Bear Mountain, N. Y., 140 ESE (estimated); Concord, N. H., 110 SE; Mt. Washington, N. H., 160 SE. Fastest mile, Newark, N. J., 82 mph E; Burlington, Vt., 72 SE; Block Island, 70 ESE; Albany, N. Y., 70 E.

AMS TO MEET IN MINNEAPOLIS

The American Meteorological Society will hold its 113th national meeting at the Curtis Hotel, Minneapolis, Minnesota, October 9th to 11th. The Minnesota Branch of the society is making the arrangements. The luncheon and afternoon session October 11th are at the University of Minnesota Coffman Memorial Union.

There will be technical sessions on aeronautical meteorology, agricultural meteorology, bioclimatology, climatology, cloud seeding, and industrial meteorology. At the banquet on Wednesday evening, Dr. Clyde Bailey, dean of the department of agriculture of the University of Minnesota, will be the principal speaker.

FORECASTING THE WEATHER

A Statistical Study of Drainage Winds at Denver, Colorado

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WIND is one of the most important of the elements that determine the climate of a place, but it is not often realized that even relatively small slopes of the earth's surface can be important in influencing the direction of the prevailing wind. In an average year at Denver, Colorado, for example, the prevailing wind is south throughout the year, primarily because of a phenomenon known as the "drainage wind." This is known technically as a "katabatic wind," the definition of which is given by the U. S. Weather Bureau in "Weather Glossary" as, "Air flowing down an incline; caused by the cooling of surface air, which then, impelled by gravity, flows downward. Also called mountain wind, canyon wind, and gravity wind."

From textbook explanations of mountain winds and valley winds, one might get the impression that drainage winds are peculiar to mountain valley stations. This is not the case, however, along the east slopes of the Rockies, where plains stations 40 miles from the mountain range experience drainage winds of a very steady nature which frequently blow in direct opposition to the surface pressure gradient.

Denver Airport, at an elevation of 5,332 feet, is on the Great Plains about 40 miles due east of the main range of the Rockies (10,000-14,000 feet) and 18 miles east of the foothills (6,000-8,000 feet). These ranges run almost due north and south. About 40 miles south of Denver is the Palmer Lake divide, a spur that extends due east of the main range. Its altitude varies from about 8,600 feet where it joins the Rockies to about 4,000 feet near the Kansas state line. The South Platte River runs through the area from the south-southwest to north-northeast, so that air which drains from the higher elevations into the shallow valley produces a south-southwest wind at Denver. Although these winds may be varied somewhat by the existing pressure gradients, the usual direction is south-southwest.

Definition of Drainage Wind at Denver

Strict criteria were set up to define cases in which a drainage wind existed. Time and velocity limits were used to eliminate light variable winds; and since air flow under drainage conditions is usually steady flow, all gusty winds were ruled out, as well as southerly winds when showers, thunderstorms, or lightning were observed. From these considerations the following criteria were used to define a drainage wind:

a. A direction between south-southeast and southwest.

b. A minimum speed of six miles per hour, and a minimum duration of six hours with an average speed of eight miles per hour or greater for at least four hours.

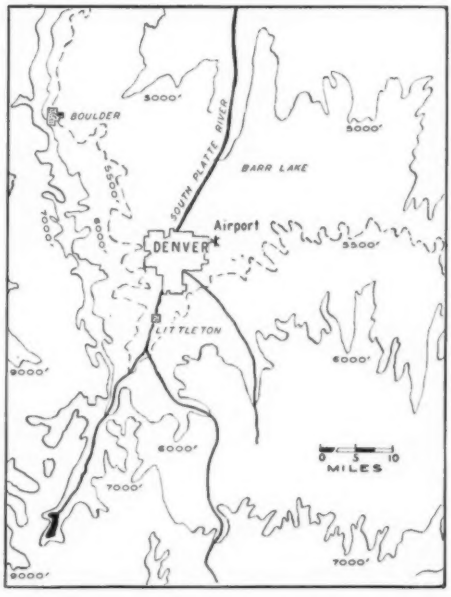
c. Must begin no earlier than one hour prior to sunset and no later than sunrise. (This criterion was set up to try to distinguish between drainage phenomena and those cases where the existing pressure gradients might produce similar winds.)

d. If southerly winds continued during the day after sunrise, the following criterion was used to determine the end of drainage. When southerly winds continued during the day and increased after 10 a.m., drainage was considered ended when the speed exceeded the minimum speed after sunrise by five miles per hour, or when gusts were reported.

e. No southerly wind was considered a drainage wind if gusts, showers, thunderstorms, or lightning were reported.

Statistics of Drainage Winds at Denver

Data for a period of four years from 1945 to 1948, inclusive, were collected. These includ-



A topographic map of the Denver area, showing the general slope downward toward the north.

ed the times of beginning and ending of the drainage winds, the average cloudiness from sunset to sunrise for all days, cloudiness prior to, at the beginning of, and during drainage, and visibility restrictions during drainage.

The following statistics were determined, irrespective of cloudiness. Drainage winds occurred on a total of 579 nights during the four years, with 6,210 hours total drainage time. This gives a yearly average of 145 nights of drainage or 39.6-per-cent frequency of occurrence, and an average duration of 10.7 hours. The distribution by months of the per-cent frequency of occurrence of nights with drainage winds and the distribution of the average duration are shown in the first two columns of Table I. The greatest frequency is in October, with drainage occurring 55 per cent of the nights in this month of least weather, and the lowest in May with a frequency of 25 per cent, when cloudiness is at a maximum. The longest average duration occurs in December, when the longest nights occur, with an average of 12.4 hours; and the shortest 9.3 hours, through April, May, and June, the months of maximum cloudiness and shortest nights.

For all months the diurnal variation of times of beginning and ending of drainage winds is plotted here. This variation is in part, of course, due to the definition which was adopted. The maximum number of cases, 91 out of 579, began between 8:00 and 8:59 p.m. The beginning time varied with season and generally reached a maximum between one and three hours after sunset. A secondary maximum occurred in many of the monthly curves (not shown) and in the annual curve near midnight. This secondary maximum is unexplained. A maximum of 96 drainages ended between 8:00 and 8:59 a.m. In the warm months, April through October, they ended in the forenoon with a definite maximum about three hours after sunrise, while during November through March they showed a more indefinite maximum, with many cases trailing into the early afternoon.

Hours of restricted visibility totaled less than 1/10 of one per cent. Restricted visibilities, however, are associated with the sudden stopping of the drainage wind in the early morning and the onset of a light northwest wind, which creates a local upslope condition from the South Platte River to the airport, with consequent fog formation and advection of industrial smoke. Zero-zero conditions often result and constitute a very difficult forecast problem.

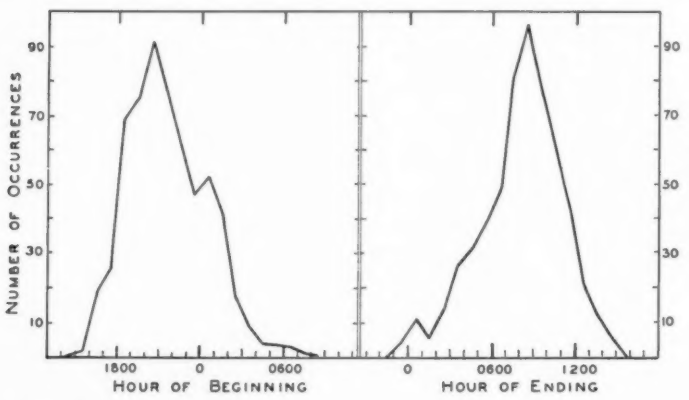
Table I. Drainage Wind Statistics at Denver

	A	B	C	D	E
January	44%	11.9h	54%	31%	4%
February	32	10.8	40	27	2
March	37	10.4	49	23	2
April	35	9.3	41	33	0
May	25	9.3	39	12	0
June	32	9.3	40	20	0
July	39	9.4	39	25	9
August	47	10.4	54	27	5
September	41	11.1	52	26	0
October	55	11.2	68	30	0
November	41	11.4	47	30	4
December	46	12.4	54	40	2
Annual	39.6%	10.7h	48.6%	26.5%	1.8%

A is the frequency of occurrence for all days; B, the average duration in hours; C, frequency with clear to scattered clouds; D, frequency with broken to overcast above 10,000 feet; E, frequency with broken to overcast below 10,000 feet.

Relation of Drainage Winds to Cloudiness

The basic concept of a drainage wind is that it will occur under conditions favorable to strong terrestrial radiation. This is borne out by the survey of mean cloudiness during the nighttime hours. The last three columns of Table I show the relationship of the occurrence of drainage winds to (**C**) clear to scattered clouds, (**D**) broken to overcast above 10,000 feet, and (**E**) broken to overcast below 10,000 feet. The annual frequency of occurrence with clear to scat-



The diurnal distribution of the time of beginning and the time of ending of drainage winds at Denver, Colorado, based on four years of data, 1945-1948, inclusive. USWB chart.

tered clouds is about 49 per cent, as compared with the overall frequency of 39.6 per cent. The frequency with broken to overcast clouds above 10,000 feet is 26.5 per cent, while the frequency with broken to overcast clouds below 10,000 feet, 1.8 per cent, is far less than the overall frequency. The maximum frequency with broken to overcast below 10,000 feet is in July, nine per cent, and at this time of year ceilings are seldom less than 6,000 feet and cloud cover seldom greater than broken, allowing good radiation even though ceilings are recorded below 10,000 feet.

That drainage is a phenomenon of fair weather is further borne out by the fact that cloudiness definitely decreases prior to commencement of the drainage. Table II shows the joint relationship between cloudiness during the three hours preceding the beginning and the cloudiness at the beginning of drainage. In 79.3 per cent of the cases there was no change in cloudiness, with 59.4 per cent remaining clear to scattered. There were only 3.3 per cent of the cases which had an actual increase in cloudiness; in most of these a clear sky changed to scattered, broken, or overcast above 10,000 feet. On the other hand, there were 17.4 per cent of the cases which had a decrease in cloudiness, with 13.8 per cent going from broken or overcast above 10,000 feet to clear or scattered.

Table II

	C′	D′	E′	Total
C″	59.4%	13.8%	1.9%	75.1%
D″	3.0	18.5	1.7	23.2
E″	0.0	0.3	1.4	1.7
Total	62.4%	32.6%	5.0%	100.0%

For cloudiness during the three hours preceding the beginning of drainage, C′, D′, and E′ represent clear to scattered, broken to overcast above 10,000 feet, and broken to overcast below 10,000 feet, respectively. C″, D″, and E″ represent the respective cloudiness conditions at the time of beginning of drainage. The percentages show the frequencies of drainage winds occurring under these conditions.

Predominance of fair weather at Denver explains the great percentage of cases preceded by clear skies or scattered clouds. A study of individual cases, however, relates the earliest time of beginning and the most intense drainage with overcast skies during the day and clearing in the late afternoon or early evening. This condition is further strengthened in the winter months if snow has fallen during the day.

Summary

Drainage winds occur at Denver Airport on about 40 per cent of all nights, with an average duration of nearly 11 hours. On the average, drainage begins between 8:00 and 9:00 p.m. and ends between 8:00 and 9:00 a.m. Occurrences are most frequent in autumn and early winter, and least frequent in May. The average duration varies from 9.3 hours in April, May, and June, to 12.4 hours in December. They are predominantly a fair-weather phenomenon, occurring almost entirely with clear skies or high cloudiness. Visibility is affected only favorably, never remaining restricted during hours of drainage.

HOT THUNDERSTORM

A thunderstorm that brought a rapid 32-degree rise in temperature as it passed over Perrin Air Force Base in Texas has been reported by Capt. W. T. Johnson, station weather officer. At 7:00 a.m. CST, a thunderstorm approached the air base and showers commenced and continued until 10:00 a.m. The temperature at 7:30 was 66° F., the dew point 66° F., and the relative humidity was 100 per cent.

A gradual temperature rise set in and became quite rapid after 8:30, the mercury rising from 72° to 86° F. in the next 15 minutes. After several fluctuations the temperature finally hit a high of 98° at 10:10 a.m., with a relative humidity reading of 22 per cent.

Pressure fell rather steadily from 1015 millibars at 7:00 to 1010 millibars at 10:30. The wind was mainly from the southwest and west-southwest, but showed unusual variations in speed. Three peak periods were experienced at 7:30, 8:45, and 9:45 a.m., with steady 30 knots and gusts in the 40's. By 10:30, the wind had shifted to north-northeast at nine knots.

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THE SEA AROUND US

Rachel Carson. Oxford University Press, New York, 1950. 230 pages. $3.50.

FEW BOOKS in science are satisfying in themselves, and at the same time stimulate a desire for more reading and further knowledge. **The Sea Around Us** is such a work. Miss Carson has taken oceanography out of the textbooks and presented an up-to-date account of our present knowledge of the oceans. And it is all done in fascinating prose. In her pages, one feels close at all times to the mystery and to the romance of the sea. Although we are let in on many recently revealed secrets of the sea, Miss Carson concludes: "But even with all our modern instruments for probing and sampling the deep ocean, no one can say that we shall ever resolve the last, the ultimate mysteries of the sea."

The book is divided into three main parts. The first is largely historical. The origin of the earth and moon, the seas and the continents, the fishes and the animals, and, finally, the appearance of man, are told with a unity wound around the waters, showing all to have sprung from the sea and to have been constantly modified by the continuing influence of the sea.

The second section describes the state of our knowledge of the physical aspects of the seas. Here Miss Carson does not confine her attention to the surface, but takes us below for a look around at great depths, where little has hitherto been known. The effects of wind, waves, and tides are all dealt with here.

The final part treats of man and how the sea about him controls his daily life. Weathermen will be at home in her discussion of marine climatology and, especially, in the chapter, The Global Thermostat, where the seas are compared to a great air conditioner, controlling the expansion and contraction of terrain where civilization can exist. Here Miss Carson wisely follows the well-known work of Dr. C. E. P. Brooks and quotes from his **Climate Through the Ages.** The chapter ends with a five-page description of Otto Petterssen's theory of tidal cycles as the controlling factor in our climate changes.

Petterssen held that the sun, moon, and earth were in favorable position about A.D. 550 for minimum tidal effect, thus excluding cold water from Europe's shores and bringing on a period of warmth. By 1400, conditions were reversed, and a great cold period descended on temperate latitudes. We are now headed into another warm cycle that will culminate about A.D. 2400. These speculations are fascinating in themselves and do confirm many historical facts, but they still leave much unexplained, and they exclude other forces at work in our atmosphere. It seems to this reader that Miss Carson devotes an inordinate amount of space to this particular hypothesis of climatic change.

As in any book that touches on one's chosen field, the meteorologist will find small items here and there to quibble about. But the general statements and the tenor of the book ring true, and the subject of oceanography has thus been brought to a very wide public audience.

The Sea Around Us should be recommended reading for all weathermen. For the amateur, it will give a pleasing acquaintance with a companion field; for the student, it will bring a difficult subject into quick focus; for the professional, it will provide a few hours of fruitful and congenial reading. D. M. L.

EVERYDAY WEATHER AND HOW IT WORKS

Herman Schneider. McGraw-Hill Book Co., Inc., New York, 1951. $2.75.

THERE has long been the need for a popular book on meteorology that students in the elementary grades of our public schools could readily understand. In this new book, through the carefully chosen phrases of Mr. Schneider and the clever and humorous drawings of Jeanne Bendick, a perfect balance has been obtained to provide a source of information and weather lore that should prove attractive to all young folks curious about the how and why of weather.

The subject matter of the 14 chapters has been carefully chosen. The continuity is well handled to lead the novice through the fundamental factors that make up a weather situation, to the manner in which these various elements and conditions combine to produce weather changes.

It is the instrument portion that makes this book outstanding for the youngster. The simplicity of the equipment at first makes one wonder if it will actually operate accurately enough to prove of real value, but as one studies the instructions and techniques, it becomes apparent that clever designs have been worked out that will operate and provide a basic weather station for the beginner. Many further improvements and ideas will, of course, suggest themselves to the youngsters when they come to build their meteorological laboratory, and those with sufficient mechanical and engineering talent can make additional worthwhile equipment.

As one who gives lectures on weather to visiting classes during the school year, I find the material in this book refreshing and well done, and I would not hesitate to recommend it to anyone in the teen-age and younger bracket who would like to become acquainted with the weather and how it works.

ROBERT E. COX
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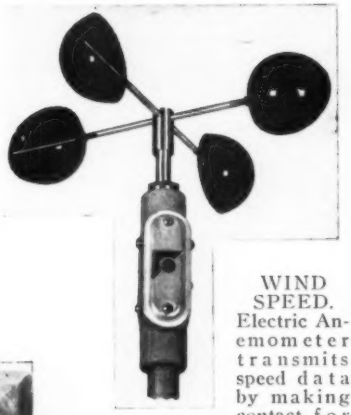

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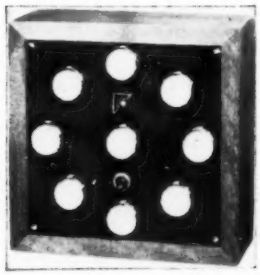

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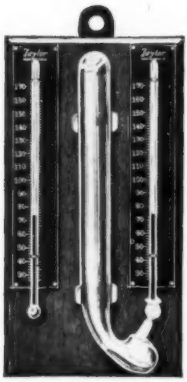

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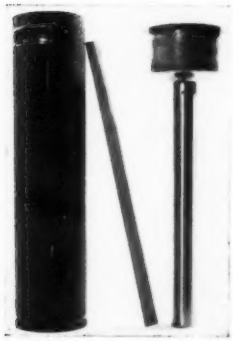

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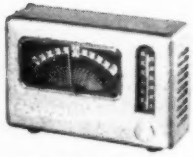

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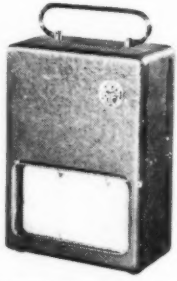

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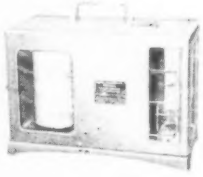

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